(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 122 810 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
08.08.2001 Bulletin 2001/32

(51) Int Cl.⁷: **H01Q 1/36**, H01Q 1/38, H01Q 1/24

(21) Application number: **00117315.2**

(22) Date of filing: **18.08.2000**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **31.01.2000 JP 2000027222**

(71) Applicant: **MITSUBISHI MATERIALS CORPORATION**
Chiyoda-ku, Tokyo (JP)

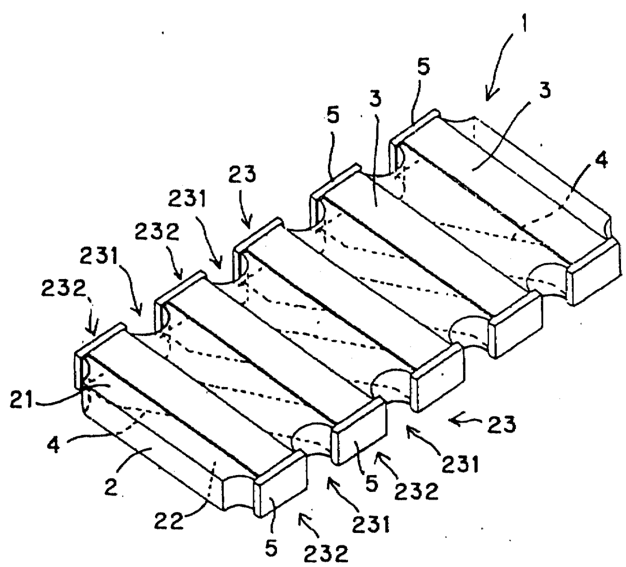
(72) Inventors:
- **Hirose, Eiichiro, Mitsubishi Materials Corp. Chichibu-gun, Saitama-ken (JP)**
- **Toyoda, Akikazu, Mitsubishi Materials Corp. Chichibu-gun, Saitama-ken (JP)**
- **Go, Yoshiomi, Mitsubishi Materials Corp. Chichibu-gun, Saitama-ken (JP)**
- **Sakai, Shinji, Mitsubishi Materials Corp. Chichibu-gun, Saitama-ken (JP)**
- **Tanidokoro, Hiroaki, Mitsubishi Materials Corp. Chichibu-gun, Saitama-ken (JP)**
- **Kitahara, Naoto, Mitsubishi Materials Corp. Chichibu-gun, Saitama-ken (JP)**

(74) Representative: **HOFFMANN - EITLE**
Patent- und Rechtsanwälte
Arabellastrasse 4
81925 München (DE)

(54) Antenna device and assembly of antenna device

(57) The present invention relates to an antenna device **1** to be used for portable communication sets and a method for reducing the manufacturing cost thereof, characterized in that the antenna device **1** comprises a substrate **2** comprising at least one of a dielectric material or a magnetic material having upper and lower faces **22** as well as a pair of side faces **23** on which convex portions and concave portions are alternately formed; and a helical conductor layer formed on the upper and lower faces **22**, and on the concave portion or convex portion on a pair of the side faces **23** of the substrate **2** so as to spirally surround the entire substrate **2**.

FIG.1



EP 1 122 810 A2

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to an antenna device to be used for portable communication sets.

2. Description of the Related Art

[0002] Although a linear antenna such as a pole antenna or a rod antenna has been used in communication sets such as a portable phone, such antenna hinders the communication set to be small size because the antenna has been attached at outside of the case of the communication set, besides causing a risk of breakage, deformation and deterioration of characteristics by suffering external mechanical forces acting on the antenna. In addition, the antenna is not preferable with respect to the packaging cost since a number of components are required for packaging the antenna via coaxial cables and connectors.

[0003] For solving the problems as described above, Japanese Unexamined Patent Application Publication No. 9-64627 proposes a compact antenna capable of surface-packaging on a circuit board as shown in FIG. 26. A helical antenna is formed within a ceramic substrate **30** by making use of a technique for forming a multi-layer ceramic substrate. A conductor line **31** is formed on each ceramic layer, and the conductor lines on different ceramic layers are connected one another via through holes **32** in which a conductive material is filled to form a helical conductor as a whole. A ceramic antenna including a helical radiation conductor is assembled by laminating the ceramic layers. A terminal **33** for feeding electricity to the helical conductor is provided on the side face of the substrate **30**.

[0004] However, since the laminated ceramic sheets are fired after forming a conductor line on each ceramic sheet before firing, the conductor line should be designed by taking shrinkage by firing into consideration. A highly rigid process control is also required in order to restrict the schrinkage ratio within a prescribed range, thus making it difficult to reduce the production cost.

[0005] Suppose that all the conductor lines are formed on the surface of the already fired ceramic sheet, but conductor patterns should be nevertheless formed on at least four faces of a ceramic block having flat surfaces by a method capable of fine control of the conductor pattern such as a printing method, also preventing the production cost from being reduced.

SUMMARY OF THE INVENTION

[0006] Accordingly, the object of the present invention in view of the circumstances as hitherto described is to provide an antenna device designed to reduce the production cost.

[0007] In a first aspect, the present invention for attaining the object above provides an antenna device comprising: a substrate comprising at least one of a dielectric material or a magnetic material having upper and lower faces as well as a pair of side faces on which convex portions and concave portions are alternately formed; and a helical conductor layer formed on the upper and lower faces, and on the concave portion or convex portion on a pair of the side faces of the substrate so as to spirally surround the entire substrate.

[0008] Preferably, at least one of the convex portions or one of concave portions on the side faces serves as a power feed electrode for feeding electricity to the helical conductor layer in the antenna device according to the present invention.

[0009] The antenna device according to the present invention preferably has a layer comprising at least one of the dielectric material and magnetic material covering at least a part of the helical conductor layer formed on the substrate.

[0010] The antenna device according to the present invention comprises a helical antenna in which a helical emission conductor is formed on the surface of the ceramic substrate, and the conductor layer on the upper and lower faces of the substrate can be formed by printing. Electrodes can be formed only on the convex portions by a high speed coating method such as a dip method or using a roll coater for forming the conductive layer on the convex portions on the side face. Using the roll coater enables superior mass-productivity to the printing method to be attained for forming the electrode particularly on the convex portion. It is also an advantage of forming the electrode on the convex portion that solders hardly form solder bridges when the solder is used for connecting the electrode on the convex portion in mounting the antenna device. When the conductive layer is formed in the concave portion on the side face, on the other hand, it can be formed by filling a conductor material in through holes to be described hereinafter, also offering an advantage that the solder bridge is hardly formed. Accordingly, the present invention can make mass-production easy besides enabling the production cost to be largely reduced.

[0011] The surface mountable type antenna can be also readily manufactured since the side face convex portions and concave portions themselves on which conductor lines are formed can be utilized as terminal electrodes.

[0012] Preferably, the antenna device according to the present invention comprises: a power feed electrode for feeding electricity to the helical conductor layer comprising one of plural portions sequentially disposed with a given distance apart on one side face of the substrate, the plural portions constituting the helical conductor layer; and an earth electrode for grounding the helical conductor layer comprising the other one of plural portions sequentially disposed with a given distance apart on one side face of the substrate, the other plural portions constituting the helical conductor layer.

[0013] The side face convex portion or the side face concave portion itself may be utilized as a power feed electrode and an earth electrode as described above. Providing a dielectric layer or a magnetic layer so as to cover the helical conductor enables the antenna device to be more compact.

[0014] It is preferable that the antenna device comprises: a power feed electrode for feeding electricity to the helical conductor layer comprising a portion located at one end of the plural portions sequentially disposed with a given distance apart on one side face of the substrate, the plural portions constituting the helical conductor layer; an earth electrode for grounding the helical conductor layer formed at an adjoining position to the power feed electrode with a given distance apart to the power feed electrode on the same side face of the substrate as the side face on which the power feed electrode is formed; and a connection conductor layer extending from the earth electrode for connecting the earth electrode to the power feed electrode in collaboration with a part of the helical conductor layer by allowing the connection conductor layer to connect to the helical conductor layer via the upper face of the substrate.

[0015] It is also preferable that the antenna device according to the present invention comprises: a power feed electrode for feeding electricity to the helical conductor layer comprising a portion located at one end of the plural portions sequentially disposed with a given distance apart on one side face of the substrate, the plural portions constituting the helical conductor layer; an earth electrode for grounding the helical conductor layer formed at an adjoining position to the power feed electrode with a given distance apart to the power feed electrode on the same side face as the side face of the substrate on which the feed electrode is formed; and a connection conductor layer extending from the earth electrode for connecting the earth electrode to the power feed electrode in collaboration with a part of the helical conductor layer by allowing the connection conductor layer to connect to the helical conductor layer via the upper face of the substrate and the side face opposed to the side face on which the earth electrode is formed.

[0016] Resonance frequencies of the antenna may be largely distributed in the present invention when the conductor pattern is formed so that the power feed electrode is connected to the earth electrode on the lower face of the substrate making contact with the circuit substrate.

[0017] Allowing the power feed electrode to be connected to the earth electrode on the upper face or on the side face can eliminate the drawbacks as described above to enable a highly precise antenna to be constructed.

[0018] In a second aspect, the present invention provides an assembly of an antenna device comprising an antenna device having a substrate comprising at least one of a dielectric material and a magnetic material and having an upper face and a lower face as well as a pair of side faces on which concave portions and convex portions are alternately formed, and a helical conductor layer formed on the upper and lower faces, and on the concave portion or convex portion on a pair of the side faces of the substrate so as to spirally surround the entire substrate; and a circuit board mounting the antenna device so as to allow the lower face of the antenna device to contact the circuit board, wherein the antenna device comprises: a power feed electrode for feeding electricity to the helical conductor layer comprising a portion located at one end of plural portions sequentially disposed with a given distance apart on one side face of the substrate, the plural portions constituting the helical conductor layer; an earth electrode for grounding the helical conductor layer formed at an adjoining site to the power feed electrode with a given distance apart to the power feed electrode on the same side face of the substrate as the side face on which power feed electrode is formed; and a connection conductor layer extending from the earth electrode for connecting the earth electrode to the power feed electrode in collaboration with a part of the helical conductor layer by allowing the connection conductor layer to connect to the helical conductor layer via the upper face of the substrate, the connection point between the helical conductor layer and the connection conductor layer on the lower face of the antenna device being free from contact with the circuit board.

[0019] The assembly of the antenna device according to the present invention comprises an antenna device in which the power feed electrode is connected to the earth electrode on the lower face of the substrate. Since the contact point between the helical conductor layer and earth conductor layer of the antenna device is made to be free from direct contact with the circuit substrate, a highly accurate antenna can be obtained by suppressing distribution of the resonance frequency of the antenna, as in the case when the contact point is formed on the upper face or side face of the substrate of the antenna device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. 1 shows a perspective view of the antenna device according to the first embodiment of the present invention.

[0021] FIG. 2 shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 1;
[0022] FIG. 3A shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 1;
[0023] FIG. 3B shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 1;
[0024] FIG. 4 shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 1;
[0025] FIG. 5 shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 1;
[0026] FIG. 6 shows, a perspective view of the antenna device according to the second embodiment of the present invention.
[0027] FIG. 7 shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 2;
[0028] FIG. 8 shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 2;
[0029] FIG. 9A shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 2;
[0030] FIG. 9B shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 2;
[0031] FIG. 10 shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 2;
[0032] FIG. 11 illustrates a method for evaluating the antenna device;
[0033] FIG. 12 shows a graph showing the relation between the reflection loss and frequency characteristics of the antenna device;
[0034] FIG. 13 shows an emission pattern on the XY-plane in FIG. 11;
[0035] FIG. 14 shows a perspective view of the antenna device according to the third embodiment of the present invention;
[0036] FIG. 15 shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 14;
[0037] FIG. 16 shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 14;
[0038] FIG. 17 shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 14;
[0039] FIG. 18A shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 14;
[0040] FIG. 18B shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 14;
[0041] FIG. 19 shows an intermediate step of the manufacturing process of the antenna device shown in FIG. 14;
[0042] FIG. 20 shows a perspective view of the antenna device according to the fourth embodiment of the present invention;
[0043] FIG. 21 shows a perspective view of the antenna device according to the fifth embodiment of the present invention;
[0044] FIG. 22 shoes a perspective view of an another antenna device;
[0045] FIG. 23 illustrates the method for evaluating the antenna device;
[0046] FIG. 24 shows an assembly of the antenna device according to the first embodiment of the present invention;
[0047] FIG. 25 shows an assembly of the antenna device according to the second embodiment of the present invention; and
[0048] FIG. 26 illustrates a conventional compact antenna capable of surface packaging on a circuit board.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0049] The embodiment of the present invention will be described hereinafter.

[0050] FIG. 1 shows a perspective view of the antenna device according to the first embodiment in the present invention.

[0051] The substrate **2** of the antenna device **1** comprises an upper face **21** and a lower face **22**, and an a pair of the side faces **23** on which concave portions **231** and convex portions **232** are alternately formed. Conductor layer **3** for connecting corresponding convex portions **232** one another on a pair of the side faces **23** are formed on the upper face **21** of the substrate **2**. Conductor layers **4** for connecting the convex portions **232** on a pair of the side faces **23**, one on the side face and the other on the opposite side face that is shifted by one pitch from the former one, are formed on the lower face **22** of the substrate **2**. Conductor layers **5** are also formed on the convex portions **232** of a pair of the side faces **23**, and these conductor layers **3**, **4** and **5** serve as a helical conductor layer for surrounding the substrate **2** as a whole.

[0052] The preferable substrate **2** has a stable specific dielectric constant (εr) or a stable specific magnetic permeability (μr) with a low loss and a small temperature coefficient (τr) of the resonance frequency. An alumina based ceramic (εr = 8.5, Q = 1000 and τr = 38 ppm/°C at 2 GHz) was used in this embodiment. The preferable conductor comprises a low resistance conductor such as copper, silver and gold. A silver-platinum paste (QS-171 made by Dupont CO.) was used in this example.

[0053] The method for manufacturing the antenna device **1** will be described hereinafter with reference to FIGS. 2 to 5 showing the manufacturing process of the antenna device **1** shown in FIG. 1. An alumina substrate **9** shown in FIG. 2 is firstly prepared. Snap lines **10** are provided on the alumina substrate **9** so as to be able to divide the substrate into a desired size in the steps hereinafter. Through holes **11** are also provided at desired sites on the snap lines. The snap lines **10** were disposed by a distance of 5 mm apart along the vertical direction and by a distance of 10 mm apart along the transverse direction, and the through holes **11** with a diameter of 0.8 mm were disposed by a distance of 2 mm apart on the snap lines along the transverse direction on the alumina substrate with a width of 50 mm, a length of 50 mm and a thickness of 1 mm.

[0054] Subsequently, conductor patterns **12** and **13** as shown in FIG. 3A and FIG. 3B were formed on the upper face **91** and lower face **92**, respectively, of the alumina substrate **9**. The patterns were formed by screen-printing a conductive paste to subject the pattern to firing at 850°C after drying.

[0055] The alumina substrate **9** after forming the upper and lower conductors were divided along the snap lines on which the through holes had been formed as shown in FIG. 4. After previously spreading a conductor paste **15** to a thickness of about 0.2 mm on a flat plate **14** such as a glass plate using a squeezer, convex portions formed on the alumina substrate by the through holes were dipped into the conductor paste **15** to coat only the tips of the convex portions with the conductor paste **15** followed by drying and firing.

[0056] As shown in FIG. 5, an antenna device **1** was finally obtained by dividing the flat plate into minimum units along the snap line. A lot of the antennas having such construction as described above can be manufactured at a time to enable a cost reduction effect to be exhibited.

[0057] FIG. 6 shows a perspective view of the antenna device according to the second embodiment in the present invention.

[0058] The substrate **2** of this antenna device **1** comprises an upper face **21**, a lower face **22** and a pair of side faces **23** on which concave portions **231** and convex portions **232** are alternately formed as in the substrate **2** of the antenna device **1** shown in FIG. 1. However, the conductor layer of the antenna device **1** shown in FIG. 6 is a little different from the conductor layer of the antenna device shown in FIG. 1. In the antenna device **1** shown in FIG.6, the conductor layer **3** for connecting between a pair of the concave portions **231** with each other is formed on the upper face **21**, the conductor layer **4** for connecting one concave portion to the other concave portion that is shifted by one pitch from the former one is formed on the back face **22**, and the conductor layer **5** is formed on the inner wall face of the concave portion, thereby forming a helical conductor layer with the conductor layers **3**, **4** and **5**. However, these conductor layers **3**, **4** and **5** also serve as a helical conductor layer for surrounding the substrate **2** as a whole, as in the antenna device shown in FIG. 1.

[0059] The preferable substrate **2** of the antenna device **1** shown in FIG. 6 also has a stable specific dielectric constant (εr) or a stable specific magnetic permeability (μr) with a low loss and a small temperature coefficient (τr) of the resonance frequency, as in the antenna device shown in FIG. 1. An alumina based ceramic (εr = 8.5, Q = 1000 and τr = 38 ppm/°C at 2 GHz) was used in this embodiment. The preferable conductor comprises a low resistance conductor such as copper, silver and gold. A silver-platinum paste (QS-171 made by Dupont CO.) was used in this example.

[0060] The method for manufacturing the antenna device shown in FIG. 6 will be described hereinafter with reference to FIGS. 7 to 10 showing the manufacturing process of the antenna device **1** shown in FIG. 6. Snap lines **10** are provided on the alumina substrate **9** as shown in FIG. 7 so as to be able to divide the substrate into a desired size in the steps hereinafter. Through holes **11** are also provided at desired sites on the snap lines. The snap lines **10** were disposed by a distance of 5 mm apart along the vertical direction and by a distance of 10 mm apart along the transverse direction, and the through holes **11** with a diameter of 0.8 mm were disposed by a distance of 2 mm apart on the snap lines along the transverse direction on the alumina substrate **9** with a width of 50 mm, a length of 50 mm and a thickness of 1 mm.

[0061] After filling the conductor paste into the through holes on the alumina substrate **9** by printing as shown in FIG. 8, the paste was fired at 850°C after drying to complete through hole conductors **14**.

[0062] Subsequently, conductor patterns **12** and **13** were formed by printing as shown in FIG. 9A and FIG. 9B, respectively, on the upper face **91** and lower face **92** of the alumina substrate **9**.

[0063] The antenna device **1** is finally obtained by dividing the substrate into minimum units along the snap lines **10** as shown in FIG. 10. A lot of the antennae having such construction as described above can be manufactured at a time to enable a cost reduction effect to be exhibited.

[0064] While two embodiments have been described herein, a layer having the same quality as the alumina substrate **9** may be formed on the conductor layer formed on the alumina substrate before or after dividing the alumina substrate **9** in either of these embodiments, thereby allowing an antenna for use in the same transmission and reception band to be more compacted.

[0065] The performance of the antenna device manufactured as described above will be described hereinafter. The antenna device shown in FIG. 1 will be explained herein.

[0066] The antenna device **1** was mounted on a evaluation substrate with a length of 25 mm, a width of 50 mm and a thickness of 0.8 mm as shown in FIG. 11. A strip line **17** and a ground face **18** are formed on the surface and back face of the insulation substrate **16** in this evaluation substrate. Electricity is supplied from a SMA connector **19** at one end to the antenna device **1** at the other end via the strip line **17.**

[0067] The relation between the reflection loss and frequency characteristics is shown in FIG. 12. The resonance frequency was 2448 MHz and the reflection loss was -6 dM or below at a band width of 133MHz.

[0068] The radiation pattern on the XY plane in FIG. 11 is shown in FIG. 13. Radiation gain turned out to be approximately omnidirectional in this face, while the maximum gain was -0.7 dBi and the minimum gain was -2.3 dBi.

[0069] While the antenna device having the construction as shown in FIG. 6 has been evaluated, the result was almost identical to the evaluation result of the antenna device having the construction as shown in FIG. 1. Accordingly, explanations thereof will be omitted herein.

[0070] FIG. 14 shows a perspective view of the antenna device according to the third embodiment in the present invention.

[0071] The substrate **2** of the antenna device **1** comprises an upper face **21** and a lower face **22**, and a pair of side faces **23** on which concave portions **231** and convex portions **232** are alternately formed. Conductor layers **3** for connecting between corresponding two convex portions **232** on a pair of the side faces **23** are formed on the upper face **21** of the substrate **2**. Conductor layers **4** for connecting the convex portions **232** on a pair of the side faces **23**, one on the side face and the other on the opposite side face that is shifted by one pitch from the former one, are formed on the lower face **22** of the substrate **2**. Conductor layers **5** are also formed on the concave portions **232** on a pair of side faces **23**, and these conductor layers **3**, **4** and **5** serve as a helical conductor layer spirally surrounding the substrate **2** as a whole.

[0072] The conductor layer at the most end of the conductor layers constituting the helical conductor layer, spirally surrounding the substrate as a whole, of the conductor layers **5** on one side face **23a** of a pair of the side faces **23** serves as a power feed electrode **5a**. A ground electrode **6a** is formed at the adjoining position to the power feed electrode **5a** with a given distance apart from the helical conductor layer. A connection conductor **6b** connecting the helical conductor layer to the ground electrode **6a** via the upper face of the substrate is additionally formed.

[0073] It is preferable that the preferable substrate **2** has a stable specific dielectric constant (εr) or a stable specific magnetic permeability (μr) with a low loss and a small temperature coefficient (τr) of the resonance frequency. An alumina based ceramic (εr = 8.5, Q = 1000 and τr = 38 ppm/°C at 2 GHz) was used in this embodiment. The preferable conductor comprises a low resistance conductor such as copper, silver and gold. A silver-platinum paste (QS-171 made by Dupont CO.) was used in this example.

[0074] The method for manufacturing the antenna device **1** will be described hereinafter with reference to FIGS. 15 to 19 showing the method for manufacturing the antenna device **1** shown in FIG. 14. An alumina substrate **9** as shown in FIG. 15 is firstly prepared. Snap lines **10** are provided on this alumina substrate **9** so that it can be divided into a desired size in the subsequent steps. Through holes **11** are also provided on the desired sites on the snap line. The snap lines **10** were disposed by a distance of 5 mm apart along the vertical direction and by a distance of 10 mm apart along the transverse direction, and the through holes **11** with a diameter of 0.8 mm were disposed by a distance of 2 mm apart on the snap lines along the vertical direction on the alumina substrate **9** with a width of 50 mm, a length of 50 mm and a thickness of 1 mm.

[0075] Conductor patterns **12** and **13** were then formed on the upper face **91** and lower face **92**, respectively, on the alumina substrate **9** as shown in FIGS> 16 and 17. A conductor paste was screen-printed for forming the conductor patterns, followed by firing at 850°C after drying.

[0076] The alumina substrate **9** after forming the upper and lower conductors was divided along the snap lines on which the through holes had been formed as shown in FIG. 18. After previously spreading a conductor paste **15** to a thickness of about 0.2 mm on a flat plate **14** such as a glass plate using a squeezer, convex portions formed on the alumina substrate by the through holes were dipped into the conductor paste **15** to coat only the tips of the convex portions with the conductor paste **15** followed by drying and firing.

[0077] An antenna device **1** was finally obtained by dividing the substrate into minimum units along the snap lines. A lot of the antennas having such construction as described above can be manufactured at a time to enable a cost reduction effect to be exhibited.

[0078] FIG. 20 shows a perspective view of the antenna device according to the fourth embodiment of the present invention. The difference of this embodiment from the third embodiment shown in FIG. 14 will be described hereinafter. While the ground electrode **6a** is connected to the conductor layer spirally surrounding the substrate as a whole via the connection conductor **6b** on the upper face of the substrate in the third embodiment shown in FIG. 14, the ground electrode **6a** is connected to the conductor layer via the connection conductor **6b** on the opposed side face **23b** to the side face **23a** on which the ground electrode **6a** is formed in the fourth embodiment shown in FIG. 20.

[0079] FIG. 21 shows a perspective view of an antenna device according to the fifth embodiment of the present invention.

[0080] In the fifth embodiment shown in FIG. 21, a conductor layer at the most end of the conductor layers constituting the helical conductor layer, spirally surrounding the substrate as a whole, of plural conductor layers **5** disposed on one side face **23a** serves as a ground electrode **5b**, which also serves as a ground conductor, and the conductor layer adjoining to the ground electrode serves as a power feed electrode **5a**.

[0081] FIG. 22 shows a perspective view on an another example of the antenna device.

[0082] While the antenna device itself shown in FIG. 22 is provided as a comparative example of the antenna device according to the present invention, it also serves as an antenna device for constituting an assembly of the antenna device according to the present invention to be described hereinafter.

[0083] In the antenna device shown in FIG. 22, the ground electrode **6a** is connected to the helical conductor layer surrounding the substrate as a whole with a connection conductor **6b**, via the upper face of the substrate, via the side face **23b** at the opposite side to the side face **23a** on which the ground electrode **6a** is formed, and via the lower face of the substrate.

[0084] The performance of the antenna device manufactured as described above will be described hereinafter.

[0085] The antenna device **1** was mounted on an evaluation substrate with a width of 50 mm, a length of 25 mm and a thickness of 0.8 mm as shown in FIG. 23. A strip line **17** is formed on the surface, and a ground face **18** is formed on the back face of the insulation substrate **16**, and electricity is supplied from a SAM connector **19** trough the strip line **17** to the antenna device **1** mounted on the other end of the substrate.

[0086] TABLE 1 shows the results measured as described above. The "3σ value of dispersion" denotes the 3σ value of dispersion of the resonance frequencies when a number of the antenna devices having the same specification one another are manufactured.

TABLE 1

DISPERSION OF RESONANCE FREQUENCY FROM CENTRAL FREQUENCY 2.45 GHz	
CONTACT POSITION	3σ VALUE OF DISPERSION
EXAMPLE 1: UPPER FAXE OF ANTENNA (FIG. 14)	± 30MHz
EXAMPLE 2: SIDE FACE (FIG. 20)	± 60MHz
EXAMPLE 3: TERMINAL ALSO SERVES AS CONTACT POSITION (FIG. 21)	± 62MHz
COMPARATIVE EXAMPLE: LOWER FACE (FIG.22)	± 155MHz

[0087] TABLE 1 shows that the distribution is suppressed in Examples 1 to 3 as compared with Comparative Example.

[0088] FIG. 24 shows an assembly of the antenna device according to the first embodiment of the present invention.

[0089] FIG. 24 shows a circuit board **97** viewed from the bottom face on which the antenna device **1** is mounted so that the lower face of the antenna device contacts the upper face of the substrate.

[0090] The ground electrode shown in FIG. 22 is connected to the helical conductor layer via the connection conductor layer on the lower face of the substrate in this type of the antenna device **1**. A hole **97a** piercing from the upper face to the lower face is provided on the circuit board **97** by chipping a part of the circuit board. The contact point between the connection conductor layer and the helical conductor layer on the lower face of the substrate of the antenna device **1** is just located on the hole **97a** to avoid the connection part from contacting to the circuit board **97**.

[0091] FIG. 25 shows an another assembly of the antenna device according to the second embodiment of the present invention.

[0092] FIG. 25 also shows a circuit board **97** viewed from the bottom face on which the antenna device **1** of the type shown in FIG. 22 is mounted so that the lower face of the antenna device contact the upper face of the substrate as in FIG. 22.

[0093] Although no chipped portion is provided on the circuit board **97**, the contact portion between the connection conductor and the helical conductor of the antenna device **1** is made to protrude from the circuit board **97**.

[0094] Dispersion of the resonance frequencies can be suppressed by mounting the antenna device so that a part of the circuit board is chipped or the contact portion is allowed to protrude from the circuit board, even when the contact portion is formed on the lower face of the antenna device. TABLE 2 shows the results of measurement of the dispersion of resonance frequencies of the assembly of the antenna device in the embodiments shown in FIGS. 24 and 25.

TABLE 2

DISPERSION OF RESONANCE FREQUENCY FROM CENTRAL FREQUENCY 2.45 GHz	
MOUNTING METHOD	3σ VALUE OF DISPERSION
CHIPPING OF SUBSTRATE UNDER CONTACT POINT (FIG. 24)	± 72MHz
PROTRUSION OF ANTENNA (FIG. 25)	± 68MHz

[0095] TABLE 2 shows that the dispersions of frequencies in this table are smaller as compared with the dispersion in the lowermost row in TABLE 1.

[0096] The foregoing results indicate that the antenna device and the assembly of the antenna device have sufficient performances as an antenna for the portable communication set.

[0097] According to the present invention as hitherto described, a surface packaging type antenna that is ready for mass-production and most suitable for the portable communication terminals can be provided by forming conductors on the convex or concave portions provided on the side face of the substrate, and by connecting the conductors formed on the upper and lower faces to form a helical emission member in the helical antenna in which the helical emission member is formed on the surface of the dielectric substrate.

[0098] Also, according to the present invention, dispersion of resonance frequencies can be suppressed to be smaller in the antenna device in which the helical emission member is formed on the surface of the dielectric substrate by forming the contact point between the helical conductor and the grounding linear conductor at the portion where the contact point does not make contact with the circuit board when the antenna device is mounted on the circuit board, as compared with dispersion of frequencies of the antenna device in which the contact point is formed on the surface to serve as a circuit substrate.

Claims

1. An antenna device **1** comprising:

a substrate **2** comprising at least one of a dielectric material or a magnetic material having upper and lower faces **22** as well as a pair of side faces **23** on which convex portions and concave portions are alternately formed; and
a helical conductor layer formed on the upper and lower faces **22**, and on the concave portion or convex portion on a pair of the side faces **23** of the substrate **2** so as to spirally surround the entire substrate **2**.

2. An antenna device **1** according to Claim 1,
characterized in that at least one of the convex portions or one of the concave portions on the side faces **23** serves as a power feed electrode for feeding electricity to the helical conductor layer.

3. An antenna device **1** according to Claim 1 or 2 having a layer comprising at least one of the dielectric material and magnetic material covering at least a part of the helical conductor layer formed on the substrate **2**.

4. An antenna device **1** according to Claim 1 comprising:

a power feed electrode for feeding electricity to the helical conductor layer comprising one of plural portions sequentially disposed with a given distance apart on one side face **23** of the substrate **2**, said plural portions constituting the helical conductor layer; and
an earth electrode for grounding the helical conductor layer comprising the other one of plural portions sequentially disposed with a given distance apart on one side face **23** of the substrate **2**, said the other plural portions constituting the helical conductor layer.

5. An antenna device **1** according to Claim 1 comprising:

a power feed electrode for feeding electricity to the helical conductor layer comprising a portion located at one end of the plural portions sequentially disposed with a given distance apart on one side face **23** of the substrate **2**, said plural portions constituting the helical conductor layer;
an earth electrode for grounding the helical conductor layer formed at an adjoining position to the power feed electrode with a given distance apart to the power feed electrode on the same side face **23** of the substrate **2** as the side face **23** on which the power feed electrode is formed; and
a connection conductor layer extending from the earth electrode for connecting the earth electrode to the power feed electrode in collaboration with a part of the helical conductor layer by allowing the connection conductor layer to connect to the helical conductor layer via the upper face **21** of the substrate **2**.

6. An antenna device **1** according to Claim 1 comprising:

a power feed electrode for feeding electricity to the helical conductor layer comprising a portion located at one end of the plural portions sequentially disposed with a given distance apart on one side face **23** of the substrate **2**, said plural portions constituting the helical conductor layer;
an earth electrode for grounding the helical conductor layer formed at an adjoining position to the power feed

electrode with a given distance apart to the power feed electrode on the same side face **23** as the side face **23** of the substrate **2** on which the feed electrode is formed; and

a connection conductor layer extending from the earth electrode for connecting the earth electrode to the power feed electrode in collaboration with a part of the helical conductor layer by allowing the connection conductor layer to connect to the helical conductor layer via the upper face **21** of the substrate **2** and the side face **23** opposed to the side face **23** on which the earth electrode is formed.

7. An assembly of an antenna device **1** comprising an antenna device **1** having a substrate **2** comprising at least one of a dielectric material and a magnetic material and having an upper face **21** and a lower face **22** as well as a pair of side faces **23** on which concave portions and convex portions are alternately formed, and a helical conductor layer formed on the upper and lower faces **22**, and on the concave portion or convex portion on a pair of the side faces **23** of the substrate **2** so as to spirally surround the entire substrate **2**; and a circuit board mounting the antenna device **1** so as to allow the lower face **22** of the antenna device **1** to contact the circuit board,

characterized in that the antenna device **1** comprises:

a power feed electrode for feeding electricity to the helical conductor layer comprising a portion located at one end of plural portions sequentially disposed with a given distance apart on one side face **23** of the substrate **2**, said plural portions constituting the helical conductor layer;

an earth electrode for grounding the helical conductor layer formed at an adjoining site to the power feed electrode with a given distance apart to the power feed electrode on the same side face **23** of the substrate **2** as the side face **23** on which power feed electrode is formed; and

a connection conductor layer extending from the earth electrode for connecting the earth electrode to the power feed electrode in collaboration with a part of the helical conductor layer by allowing the connection conductor layer to connect to the helical conductor layer via the upper face **21** of the substrate **2**,

the connection point between the helical conductor layer and the connection conductor layer on the lower face **22** of the antenna device **1** being free from contact with the circuit board.

FIG.1

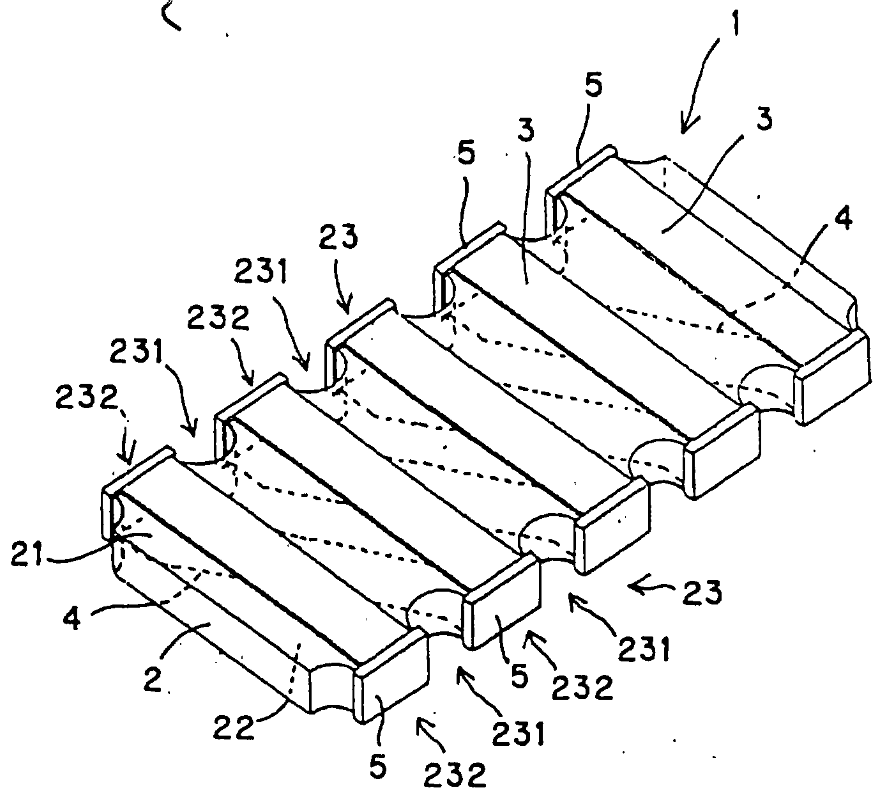


FIG.2

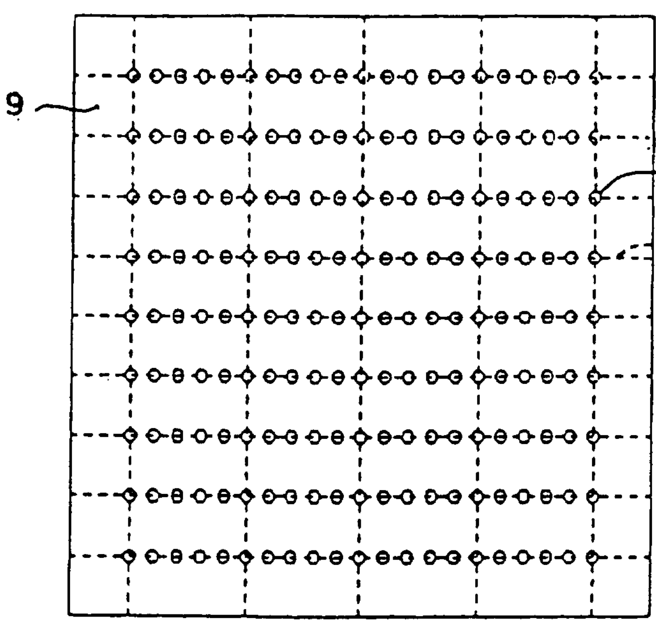
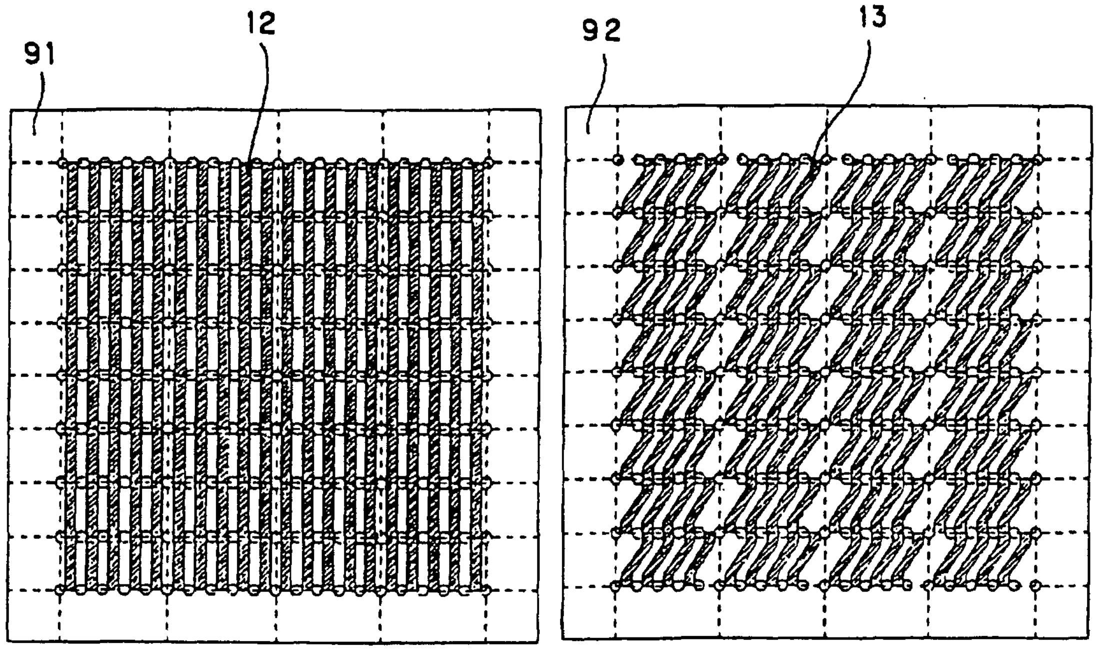


FIG.3



(A) (B)

FIG.4

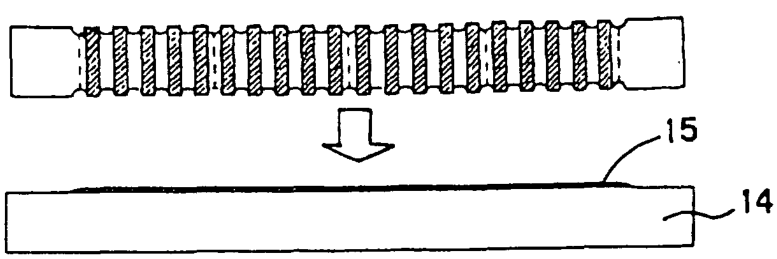


FIG.5

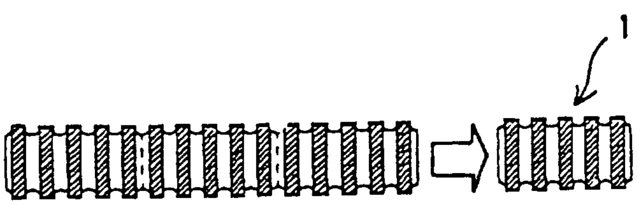


FIG.6

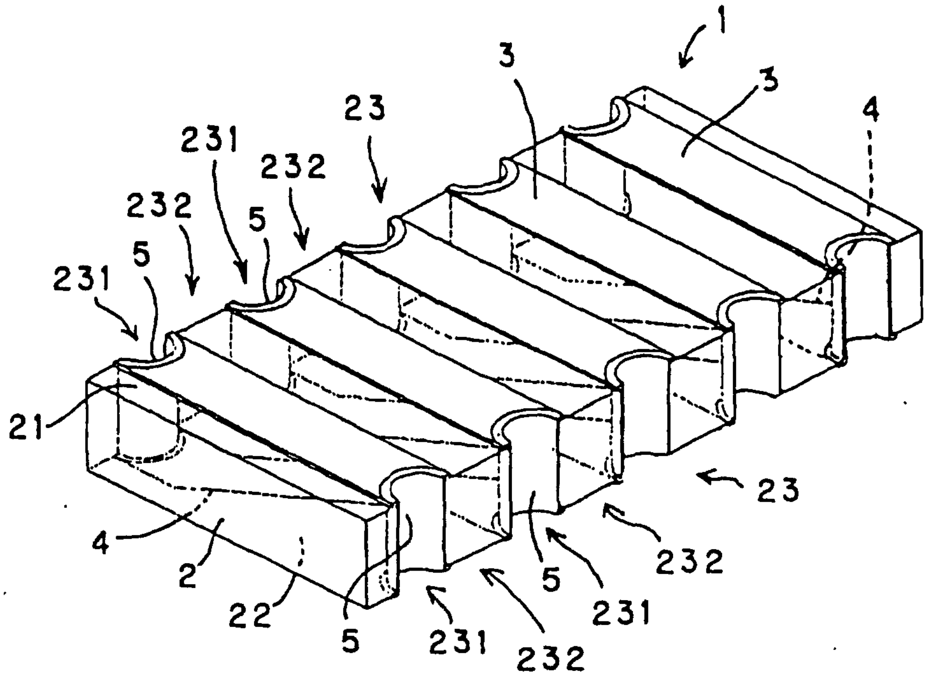


FIG.7

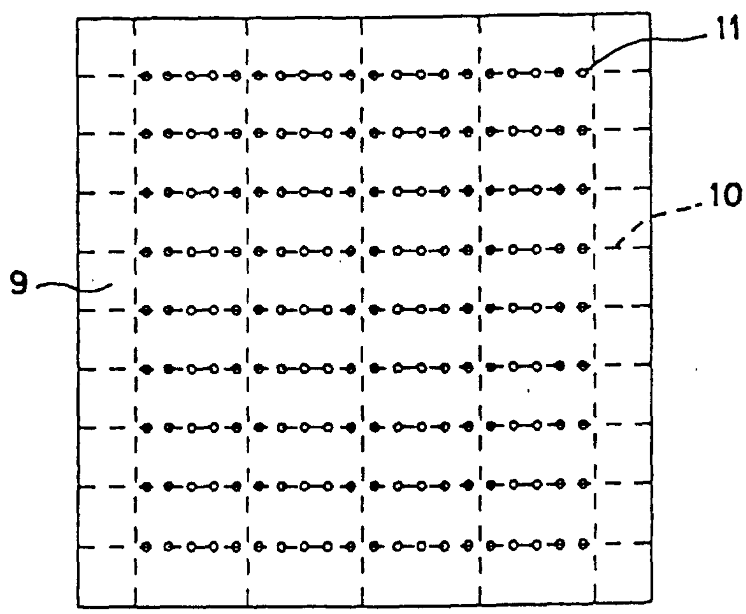


FIG.8

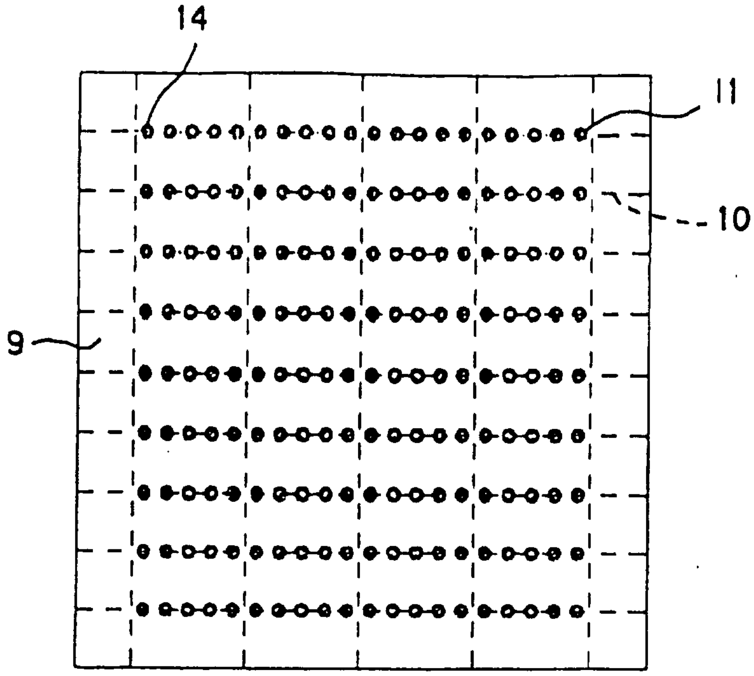
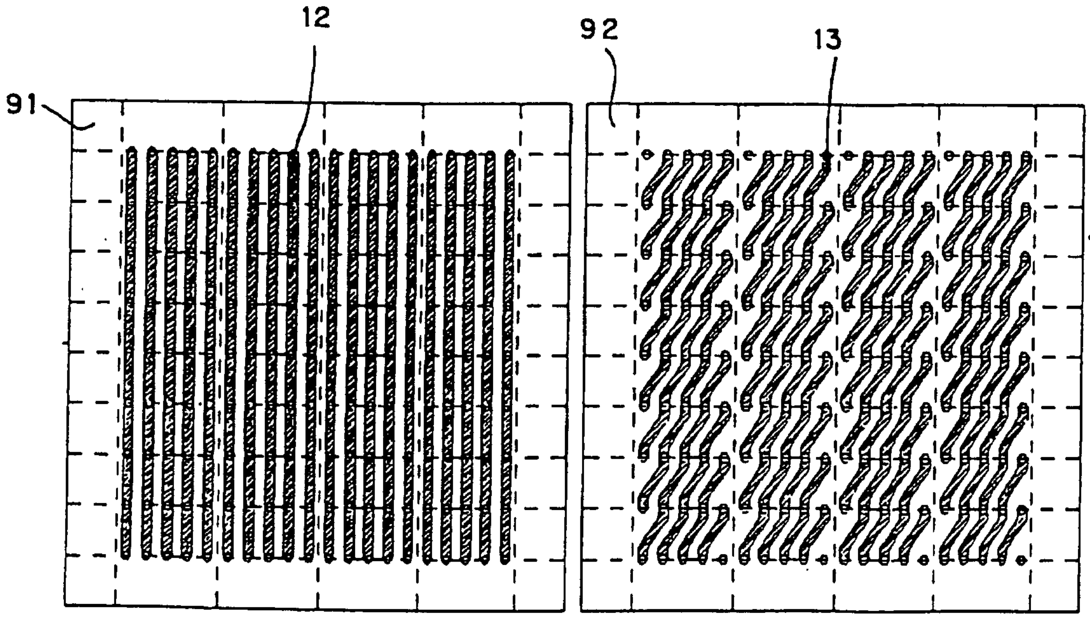


FIG.9



(A) (B)

FIG.10

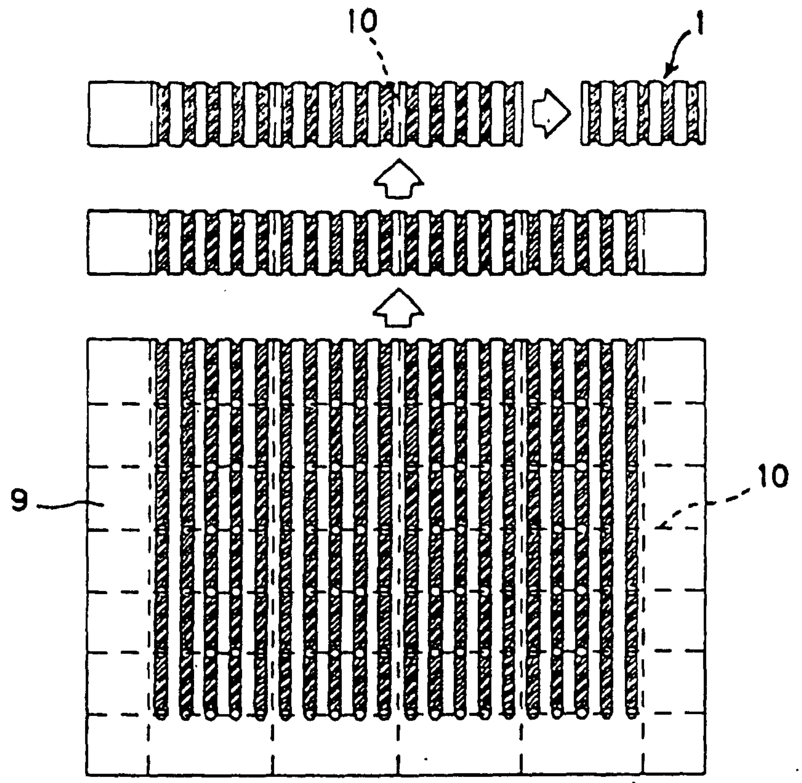


FIG.11

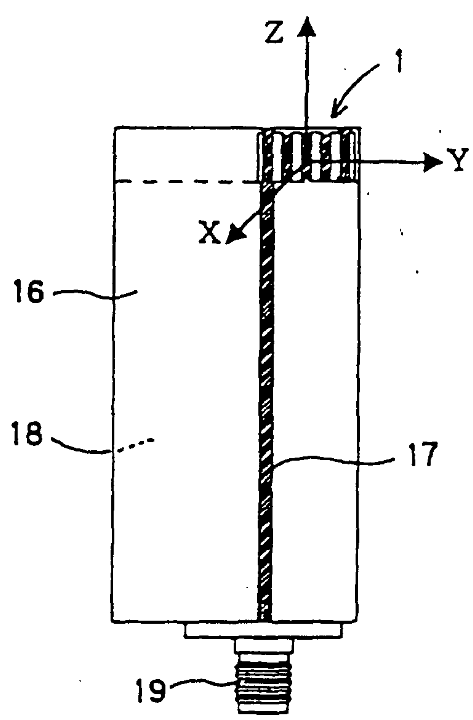


FIG.12

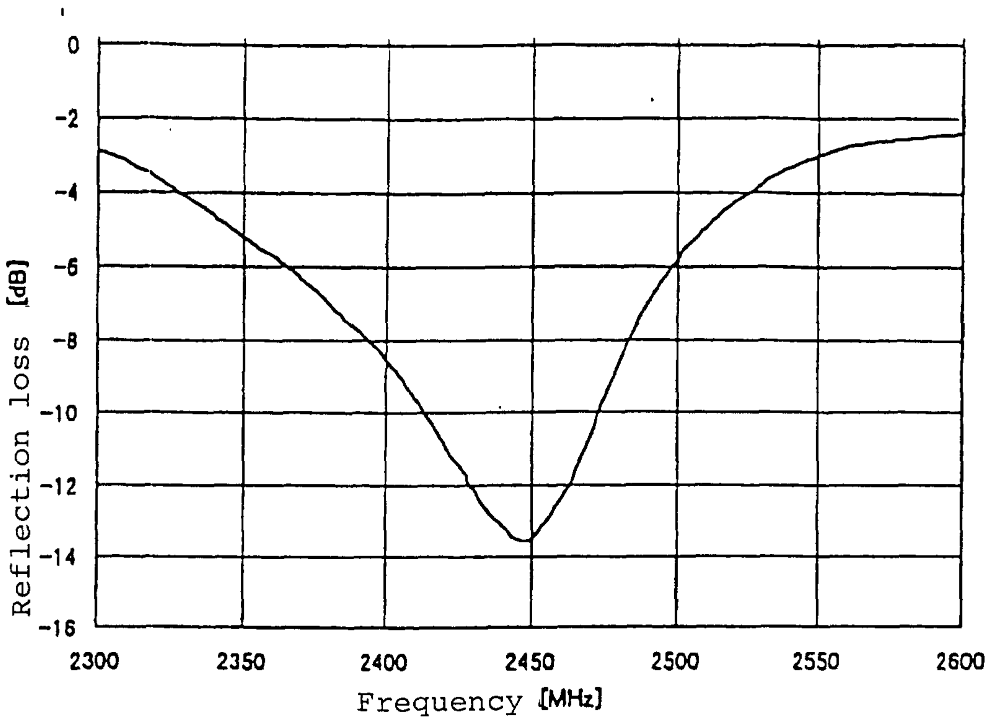

0
-2
-4
-6
-8
-10
-12
-14
-16
Reflection loss [dB]
2300
2350
2400
2450
2500
2550
2600
Frequency [MHz]

FIG.13

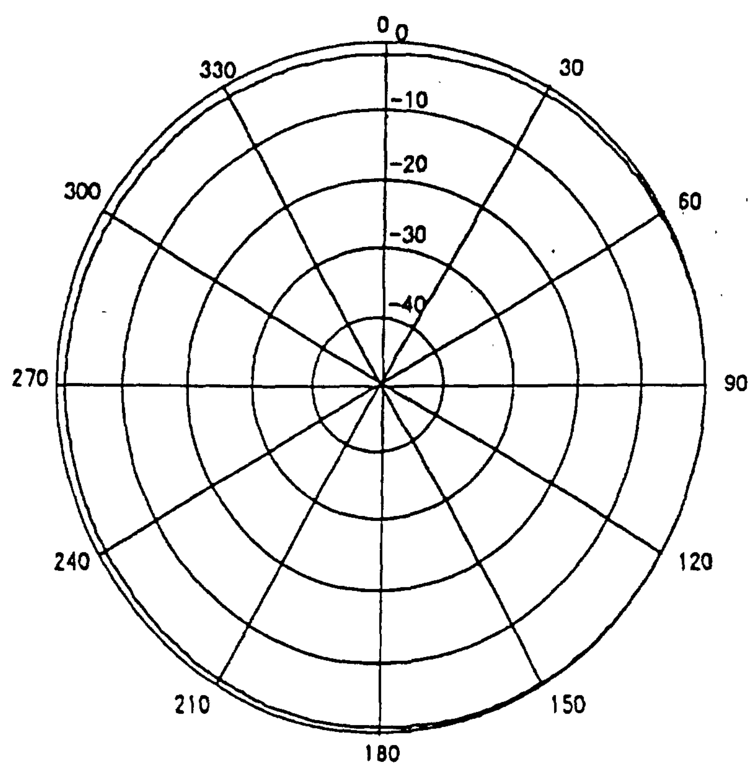

0
0
30
60
90
120
150
180
210
240
270
300
330
-10
-20
-30
-40

FIG.14

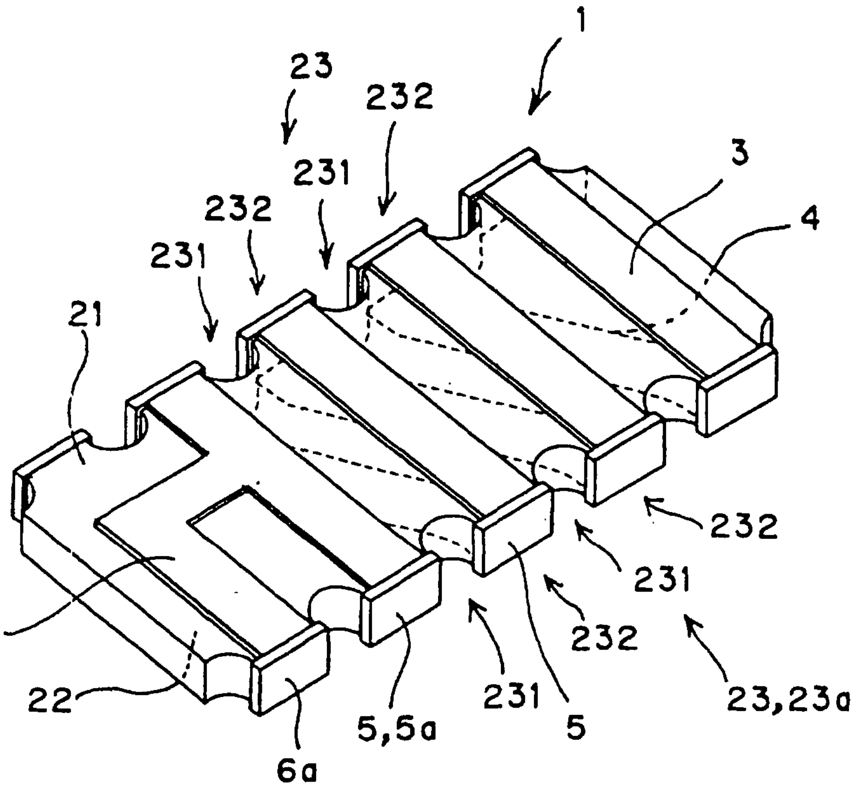

1
23
232
231
232
231
3
4
21
231
232
6b
22
6a
5,5a
231
5
232
231
232
23,23a

FIG.15

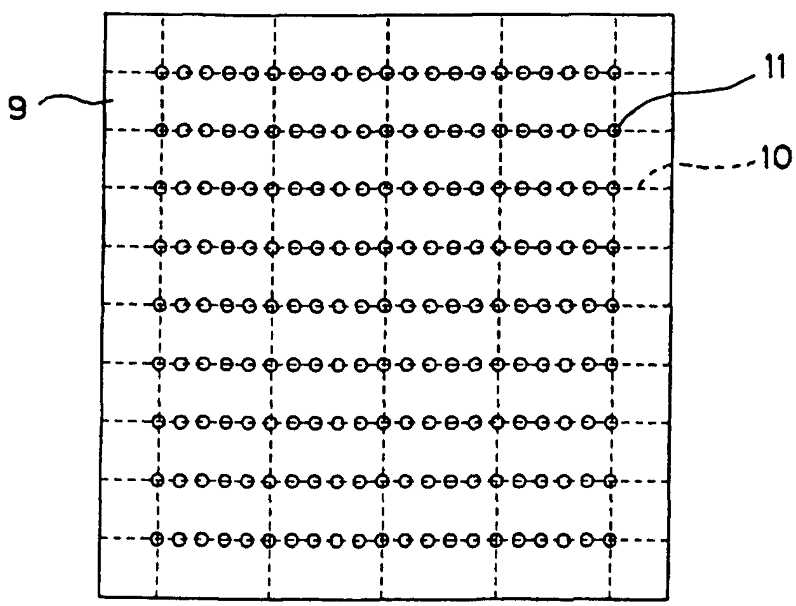

9
11
10

FIG.16

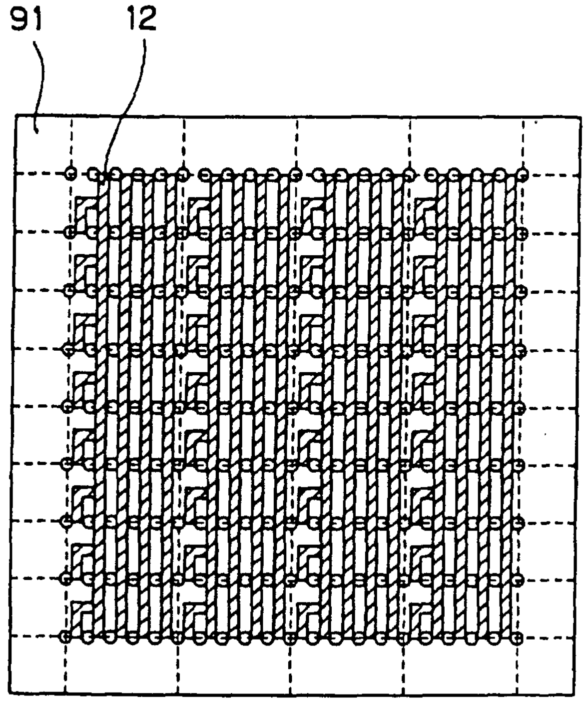


FIG.17

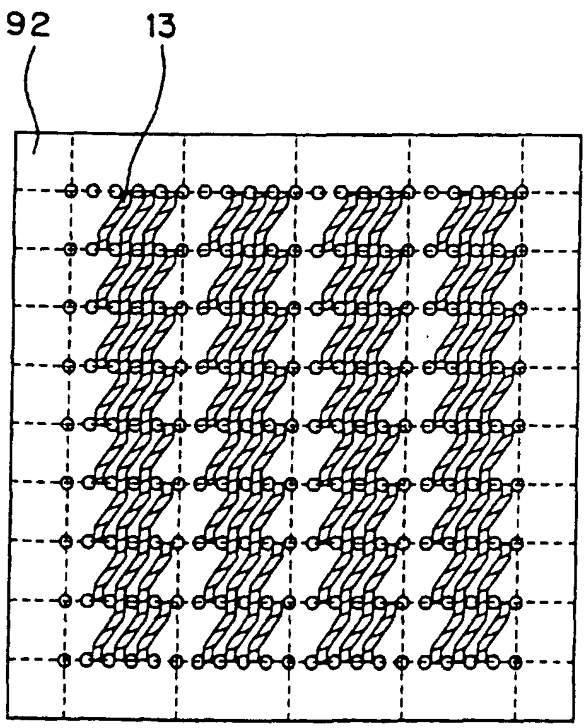


FIG.18

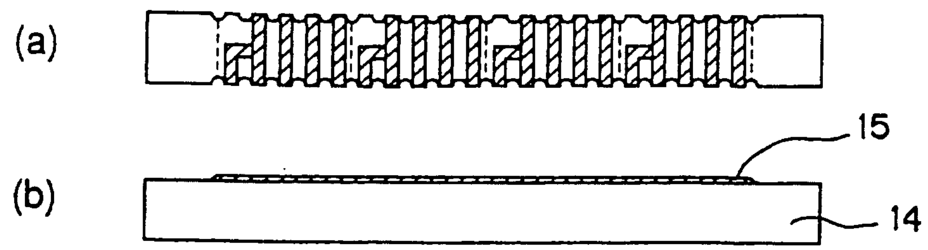


FIG.19

FIG.20

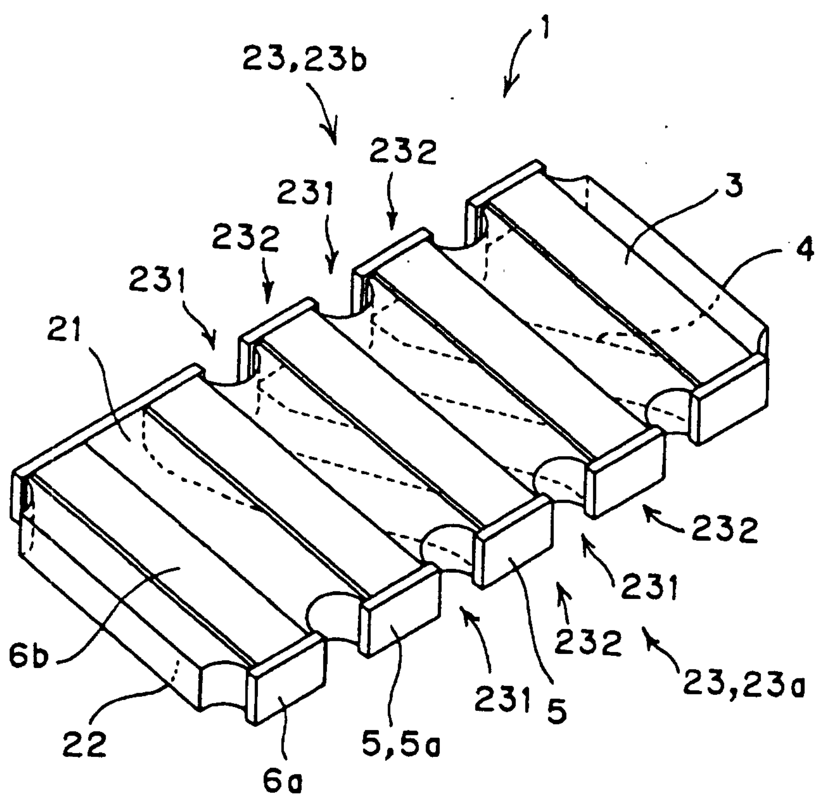


FIG.21

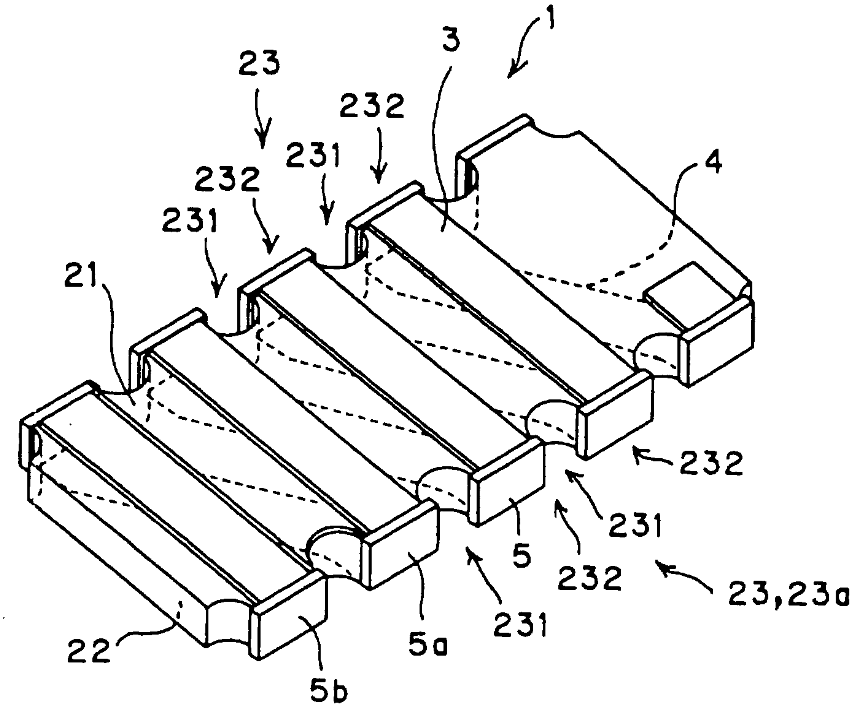

1
3
23
232
231
232
231
4
21
232
231
5
232
23,23a
231
22
5a
5b

FIG.22

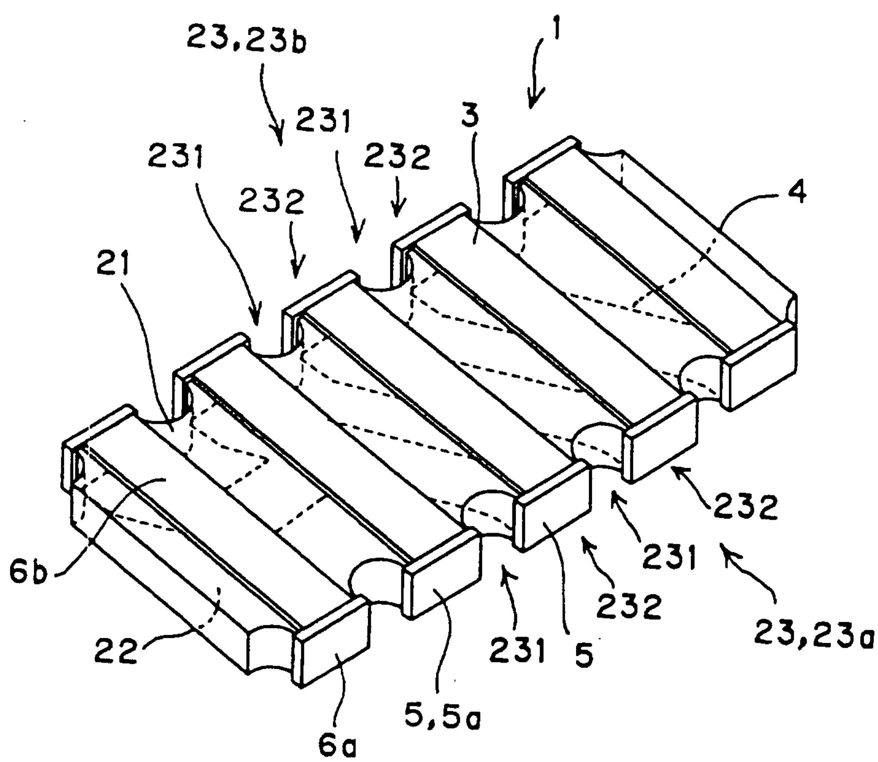

1
23,23b
231
3
232
231
232
4
21
232
231
6b
232
23,23a
22
231
5
5,5a
6a

FIG.23

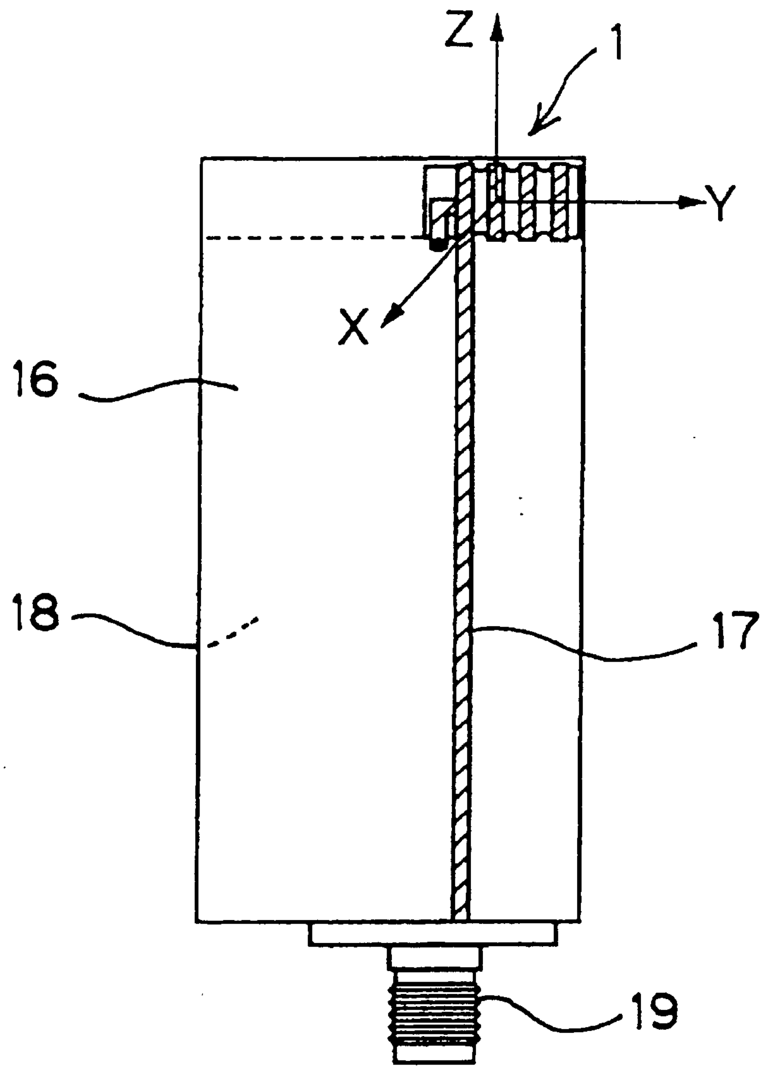


FIG.24

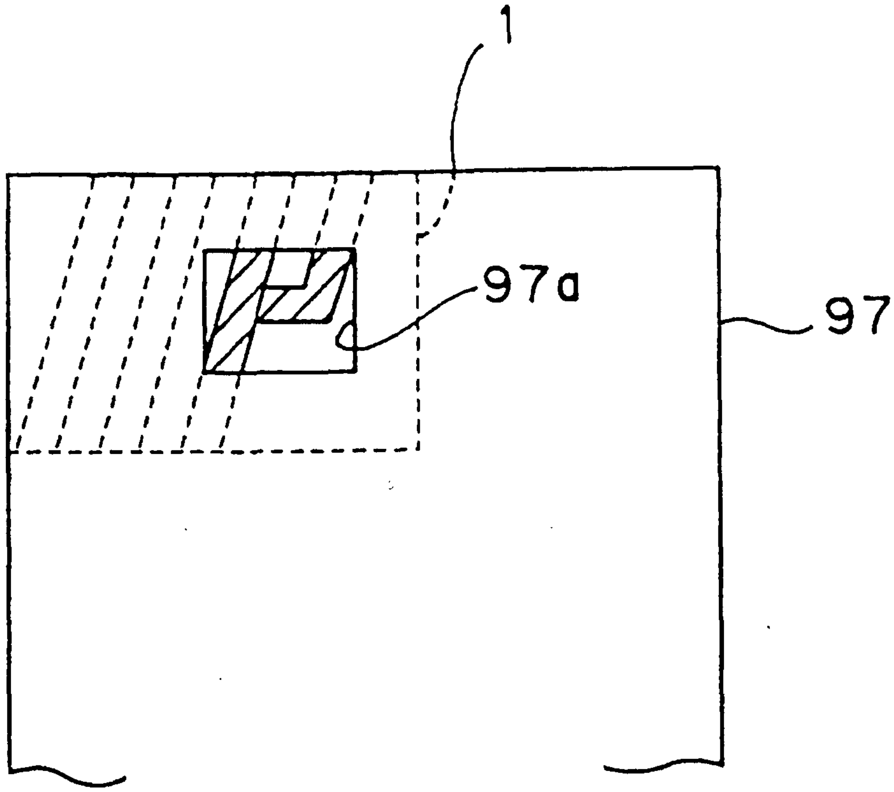


FIG.25

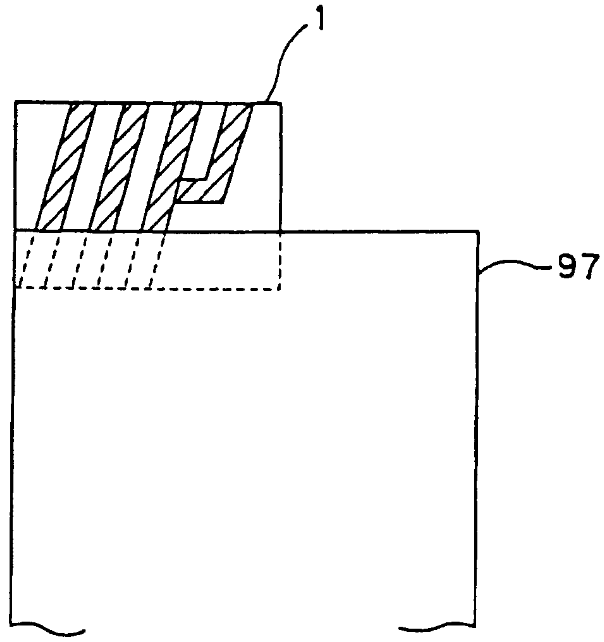


FIG.26